EXPERIMENT NO. 6

LOSSES AND EFFICIENCY OF AN ALTERNATOR

PURPOSE:

To discover the sources of losses in an alternator and to compute efficiency.

BRIEFING:

Whenever we convert one form of energy into another there are bound to be losses. No machine is perfect. Power is supplied to an alternator both in the form of electrical energy and in the form of mechanical energy. The electrical energy is supplied to the field coil. This energy is used to set up the main magnetic field. This field is constant. There is no energy taken from it in the generation of electricity. Therefore, since none of the power out comes from this energy, the power by the field must be counted as a loss.

Most of the power comes from the prime mover. Some of this mechanical power is lost to the windings and friction of the alternator. The mechanical losses do not depend on the alternator's load. To find these losses it is necessary to determine the overall mechanical losses then subtract the losses of the prime mover.

Another class of losses that does not vary with load is the core losses. We are speaking here about the armature's core. Since there is an alternating voltage generated, the core is continually becoming magnetized with one polarity, de-magnetized, then magnetized with the other polarity each cycle. All of this magnetic activity in the core causes eddy current and hysteresis losses. These core losses depend on the alternator's voltage, not on load.

As load current flows through the armature coils the resistance of the wire causes a power loss. This copper loss is proportional to the square of the current, $P = I^2R$. Copper losses, therefore, increase rapidly with load.

Percent efficiency is the ratio between the power out and the power in. % Eff. $= P_{out}/P_{in} \times 100$. If the load has unity power factor, $P_{out} = E \times I \times 1.73$. Regardless of load, $P_{in} = P_{out} +$ losses.

PERFORMANCE OBJECTIVES:

Upon successful completion of this experiment, the student will be able to:

1. Identify the sources of losses in alternators.

2. Compute efficiency given the power out and the magnitude of the losses.

MACHINES REQUIRED:

DM-100A DC machines operating as a motor
SM-100-3A Synchronous Machine operating as an alternator

POWER REQUIRED:

0 - 125 volt variable DC, 5 amps
1 - 150 volt variable DC, 1 amp

METERS REQUIRED

0 - 150 volt DC voltmeter
0 - 75/150 volt DC Voltmeter
0 - 2.5 amp DC ammeter
0 - 300 volt AC voltmeter
0 - 1.0 amp DC ammeter
0 - 0.5 amp AC Ammeter

ADDITIONAL MATERIAL REQUIRED:

MGB-100DG Bedplate
SLA-100D Strobe-Tachometer
RLC-100 Resistance/Reactance Load

PROGRAM PLAN:

A. ROTATIONAL LOSSES

step 1. Place the two machines on the bedplate. Clamp the motor but do not couple the machine.

step 2. Connect the DC machine as a shunt motor as shown in Figure 6-l.

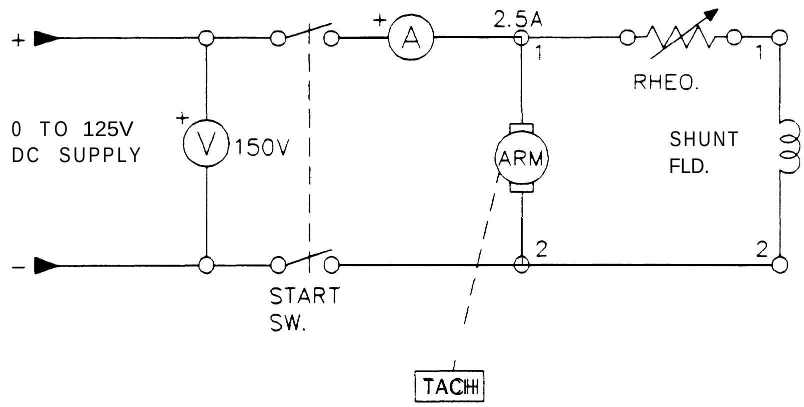

Figure 6-1

step **3.** Turn the motor's field rheostat fully counterclockwise to its minimum resistance position. Turn the voltage control knob of the 0-125V DC supply counterclockwise to its zero output position.

Step **4.** Have someone check your connections to be sure they are correct. Then turn ON the main AC, the 0 -125V DC supply, and the motor's circuit breaker. Slowly increase the output of the 0-125V supply to 125V to start the motor.

Step 5. Set the strobe-tachometer to 1800 RPM and adjust the motor's field rheostat to achieve that speed.

Step **6.** Read the motor's voltage and current and record these readings in TABLE 6-1.

step 7. Turn OFF the main AC, 125 volt and motor circuit breaker switches.

step 8. Multiply voltage and current read in Step 6 to compute rotational losses in motor.

step 9. Couple the alternator to the motor. Clamp securely. Install guards.

step 10. With no connections made to the alternator, repeat Steps 3, 4, 5, 6, and 7.

step 11. Multiply voltage and current read in Step 10 to compute total rotational losses in the motor and alternator, P_{MAL}. Record this value in TABLE 6-1.

step 12. Compute the alternator's rotational losses, P_{AL}, by subtracting P_{ML} from P_{MAL}. Record in TABLES 6-1 and 6-5.

B. DETERMINE THE ARMATURE RESISTANCE

step 13. Connect the 150 volt supply to one of the alternator's coils as shown in Figure 6-2.

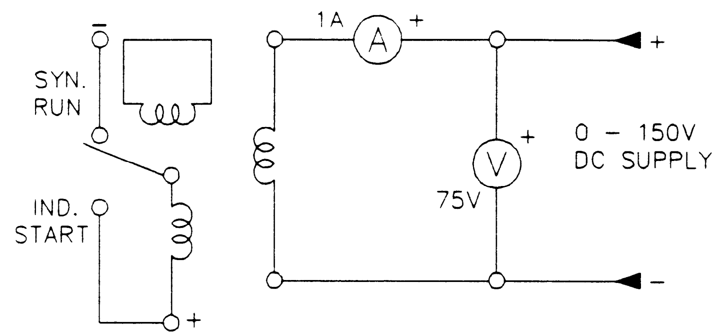

Figure 6-2

step 14. Turn the knob of the 150 volt supply fully counterclockwise to its 0 **output position,**

step 15. Turn on the MAIN AC and the 150 volt supplies.

Step 16. Slowly increase the voltage until the ammeter reads 1.0 amperes. Read the voltage and record in TABLE 6-2.

step 17. Turn off the circuit breaker switches **and** disconnect the leads **from the** alternator only.

step 18. Compute armature resistance as follows:

a) R_{DC} = E/I. Record in TABLE 6-2.

b) Multiply R_{DC} times 1.5 to find the AC resistance of one coil. Record in TABLE 6-2.

c) Multiply the result of (b) times 3 to find the total armature resistance of the 3 coils. Record in TABLE 6-2.

C. DETERMINE THE FIELD LOSS.

Step 19. Connect the field to the excitation (0-150V DC) supply and the RX-100 to the terminals as shown in Figure 6-3. Be sure all of the resistance toggle switches are in the downward (OFF) position.
Note that the alternator is **wye-connected.**

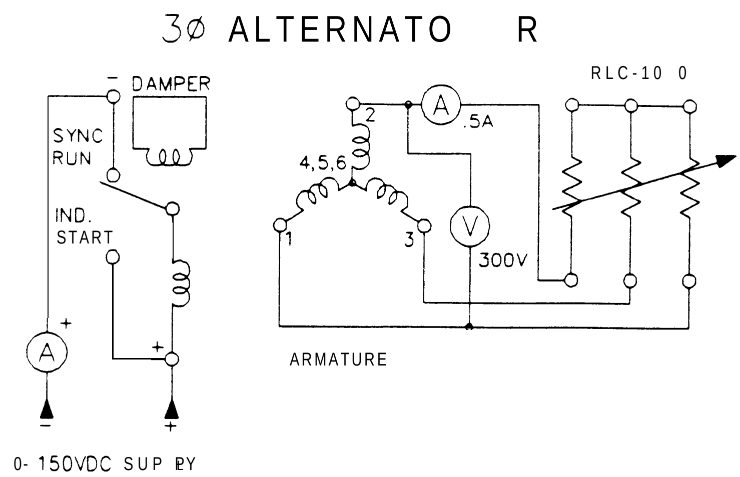

Figure 6-3

Step **20.** Repeat steps 3,4, and 5.

Step 21. Slowly increase the excitation voltage until the terminal voltage of the alternator is 208 volts.

Step 22. Read the field voltage and amps and record in TABLE 6-3.

Step 23. Multiply field volts and amps to compute field loss P_{LF}. Record in TABLE 6-3 and 6-5.

D. CORE LOSSES

Step 24. Read the motor's voltage and current and record these readings in TABLE 6-4.

Step 25. Multiply the voltage and current read in Step 24 to compute total no-load losses, P_{NLL}. Record in TABLE 6-4.

Step 26. Compute the alternator's core losses, P_{CL}, by subtracting the total rotational losses P_{MAL} from the total no-load losses, P_{NLL}. Record in TABLE 6-4 and TABLE 6-5.

E. POWER OUT

Step 27. Add 5 steps of resistance load from the RLC-100.

step 28, Repeat Step 5.

Step 29. Read the terminal voltage of the alternator and the load current. Record these values in TABLE 6-6.

Step 30. Turn **OFF all circuit breaker switches.** Disconnect all leads.

TEST RESULTS:

	E	I	E x I
UNCOUPLED MOTOR			P_{ML} = ________
COUPLED MOTOR			P_{MAL} = ________
$P_{AL} = P_{MAL} - P_{ML}$ = ________			

TABLE 6-1 - ROTATIONAL LOSSES

I	E	$R_{DC} = E/I$	$R_{DC} \times 1.5$	ARM. RES.
0.3A				

TABLE 6-2 - ARMATURE RESISTANCE

CURRENT	VOLTAGE	$P_{FL} = E \times I$

TABLE 6-3 - FIELD LOSSES

CURRENT	VOLTAGE	P_{NLL}	P_{CL} ($P_{NLL} - P_{MAL}$)

TABLE 6-4 - CORE LOSSES

ROT. (P_{AL})	
FIELD (P_{FL})	
CORE (P_{CL})	
$(I_{ALT})^2R(P_{LOAD})$	
TOTAL	

TABLE 6-5 - TOTAL LOSSES

E	I	POUT	POUT + LOSS

& EFFICIENCY = ________

TABLE 6-6 - EFFICIENCY

DE-BRIEFING:

1. From the current recorded in Step 29 and the armature resistance computed in Part B, compute the full load armature loss (I^2R). Record this value in TABLE 6-5.

2. Add the rotational, field, core, and armature losses and record the value in TABLE 6-5.

3. Compute the power output from the equation:

   P_{OUT} = E x I x 1.73. Record in TABLE 6-6.

4. Add the losses computed in #2 to the power output computed in #3. Record the value in TABLE 6-6.

5. Compute the alternator's efficiency from the equation:

$$\%\ \text{Efficiency} = \frac{\text{Power Out}}{\text{Power Out + Losses}} \times 100$$

   Record your answer in TABLE 6-6.

QUICK QUIZ:

1. Of the following types of losses, which one varies with load:

   (a) core loss

   (b) Copper loss in armature

   (c) Field loss

2. Of the following types of losses, which one is a mechanical loss:

   (a) Rotational loss

   (b) Copper loss in armature

   (c) Field loss

3. At low loads, the efficiency of an alternator is:

   (a) Greater than at rated load.

   (b) Less than at rated load.

   (c) The same as rated load.

4. Most of the electrical power delivered to the load is supplied to the alternator as:

   (a) Electrical energy to the field.

   (b) Electrical energy to the armature.

   (c) Mechanical energy in the form of torque on the rotor shaft.

5. The sum of electrical power supplied to the load and alternator losses equals:

   (a) The total power lost in the motor generator set.

   (b) The power input to the alternator.

   (c) The power supplied to the prime mover.